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Manual Evaluation of the Pelvic Floor: State of the Art and Evaluative Hypothesis

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Abstract: The pelvic floor is an anatomical area where the balance of different visceral, muscular and liquid pressures play a fundamental role in the physiological pursuit of the functions of all the structures contained therein. When the balance is broken, multiple disorders and pathologies arise, requiring conservative or surgical multidisciplinary treatments. The focus of this article is to propose a manual evaluation of the musculoskeletal structures of the pelvic floor since a complete palpatory examination taking into account the muscular, articular and ligamentous aspect of the pelvic area is currently missing. The detection of the abnormal area is a determining factor to organize properly the therapeutic work because, potentially resulting in better results. According to the Authors' knowledge, this is the first article in the current scientific landscape proposing a complete manual evaluation.

Keywords: Women’s Health, Pelvic Floor, Manual Evaluation, Pain, Osteopathic, Multidisciplinary Approach

1. Introduction

The pelvic floor is an anatomical area where the balance of the different pressures, either visceral, muscular or liquid, play a fundamental role in the physiological pursuit of the functions of all the structures contained therein. The pelvis is considered superiorly as the space between the pubic and sacral promontory through the unnamed line (present on the inner part of the iliac bone), and inferiorly as the plane between the ischiatic tuberosity and the coccyx apex, closed down from the perineum [1]. From a descriptive anatomical point of view, the pelvic floor can be divided into four compartments: anterior or urinary (bladder, bladder neck, urethra); medium or genital (vagina and uterus in women, prostate in men); posterior or anterior (anus, anal canal, sigmoid, rectum); peritoneal (endopelvic fascia, anus muscle lift, perineal membrane) [2, 3].

It can also be considered from an anatomical functional point of view, which will be taken into account by the authors to built the present article: diaphragm or pelvic floor (ischio-coccygien muscle and levator ani muscles), closed at the top by the endopelvic fascia; the urogenital diaphragm or triangular ligament or fascia of Carcassonne is placed caudally, externally and horizontally to the pelvic floor, between the ischiatic branches and the pubic symphysis, and crossed by the urethra and the vagina; the perineum or perineal membrane is the continuation of the Carcassonne fascia, connecting the deep layer of the pelvic floor musculature, the coccyx and the anal sphincter [1, 4] (see table 1).

Table 1. *Descriptive and Functional anatomy.*

Descriptive anatomy
Anterior or urinary compartment
Medium or genital compartment
Posterior or anorectal compartment
Peritoneal compartment
Functional anatomy
Diaphragm or pelvic floor
Urogenital diaphragm
Perineum

In this text we will discuss the notions of anatomy of the pelvic floor, the problems arising from a functional and pathological alteration of the muscular area, the latest instrumental and manual evaluation tools available in the literature, and the conservative treatment usually pursued.

The final part of the text deals with the article's focus, a proposal for a manual evaluation of the musculoskeletal structures forming the pelvic floor since a complete palpatory examination taking into account the muscular, articular and ligamentous aspect of the pelvic area is currently missing. The detection of the abnormal area is a determining factor to organize properly the therapeutic work because, potentially resulting in better results. According to the Authors' knowledge, this is the first article in the current scientific landscape proposing a complete manual evaluation.

2. Myofascial Anatomy of the Pelvic Floor

From an embryological point of view, the muscular pelvic part, in conjunction with the first sketches of the pelvic organs, is formed by two distinct muscle groups: the pubo-caudal muscle and the muscle of Gegenbauer (close to the cloaca) [1].

The first group will form the ischio-coccygien and the elevator ani muscle, the pubo-sacral or pubo-urethral-bladder-rectosacral ligaments in the man and pubo-ureter-bladder-uterus-rectosacral ligament in the woman; the second group will form, after the descent of the genito-urinary septum (that separates the rectum posteriorly from the bladder and urethra in the man and urethra and vagina in the woman), the sphincter muscles (the anus and the urethra) first, and the bulbocavernous, ischiocavernous and superficial and deep transverse muscles. 1 In the fetus, these muscular and ligamentous structures present themselves as a unity, synergistic in their contractions and functions [1]. The pelvic diaphragm, first named in 1861, consists of the elevator ani, formed by the coccygien muscle or ischiococcygien, ileococcygien, pubococcygien muscles and the puborectal muscle [5].

The first three originate from the pectineal line of the pubic bone and from the fascia of the obturator muscle, to fit the coccyx, through the ischiatic spine, the ileum and sacrum, and the triangular ligament (or urogenital diaphragm); the puberectal muscle involves the lower middle portion of the pubic branch [5, 6]. Pubococcyx and rectal muscles are also called pubovisceral muscles since contractile filaments are directly linked to the urethra, vagina, perineal body and anal canal, respectively such as pubourethral, pubovaginal, puboperinal and puboanal muscles [5, 6]. (see table 2)

Table 2. *Pelvic floor muscles.*

Levator ani:
Coccygeus or ischiococcygeus
Iliococcygeus
Pubococcygeus
Puborectalis
Pubovisceral muscle (Pubococcygeus and Puborectalis):
Pubourethral
Pubovaginal
Puboperineal
Puboanal

Most (around 2/3) of the contractile fibers of these muscles are red aerobic or type I fibers, while the rest is formed by anaerobic white fibers or Type II. These muscles work as a single unit and are difficult to distinguish separately; furthermore, the vectorial direction of their fibers is hard to describe because they work in all planes in a functional and anatomical tridimensionality. From tractography we can derive the organization of contractile fibers, where musculature appears as a work of art [7]. The urogenital diaphragm, placed beneath the pelvic floor, is constituted by the perineal media aponeurosis or fascia, including the deep transverse muscle of the perineum; is a reinforcement that joins the pelvic diaphragm to the perineum [1]. Its anterior part is crossed by the urinary and genital tracts, lying between the two ischiopubic branches and pointing at the apex toward the pubic symphysis; the pre-urethral area or transverse ligament of the perineum keeps in touch with the ischiopubic branches and the obturator band, while the retro-urethral area is divided into two layers (superior and inferior), with the Gouthrie's muscle or deep transverse perineum muscle placed between [1]. The upper aponeurotic lamina continues towards the transverse perineal muscle, while the deeper lamina blends with the band of Denonviller, with the latter covering the prostate and the seminal vesicles [1, 8]. The perineum is the continuation of the urogenital diaphragm posteriorly and of the elevator ani muscle inferiorly, very difficult to be delimitated; it connets with muscular fibers the urethra, the vagina or the prostate, and the rectum, up to the coccyx with an ano-coccygien rafe. The muscles and the viscera are immersed in a web of connective tissue or fascia, where just as the spider perceives the prey imprisoned thanks to the movements; all the structures immersed and wrapped in the fascia perceive the changes of tension and function in a continuum which respects the concept of biotensegrity. The biotensegrity is based on the presence of discontinuous compression elements (bones) that balance the stress generated or received by continuous tension elements (muscle and band) [9, 10]. The fascia is a mechanical transmission force instrument that involves the entire body system; a cervical flexion movement, for example, involving the deep cervical fascia, will affect the position of the lower limb band, dragging the connective tissue upward [11]. The fascial system precedes the birth and organization of contractile districts [1]. Below the peritoneum the endopelvic fascia covers the upper area of the pelvic floor: it covers the inner obtuator, the piriformis, the elevator ani, to continue with the transversal band merging into the pubic periosteum [12]. In its path it merges with the pubosacral ligament posteriorly, building a connective cup covering the entire musculoskeletal structure of the pelvic floor, the urogenital diaphragm and perineal area [1]. The endopelvic fascia encapsulates the viscera of the pelvic floor, further connecting them with musculature and bone structures; it guides the vascular structures in connective sheaths such as the hypogastric sheath (which connects the pubic bone to the sacrum), the umbilical-prevescical sheath (which delimits the retropubic space), the vescicorectal sheath for the vesicular-deferential arteries, and the aforementioned fascia of Denonvillier wrapping the two middle hemorrhoidal arteries [1, 13].

All the various visceral ligaments derive from the endopelvic fascia [13]. Pelvic muscle innervation is complex, involving the autonomic and somatic system: the superior hypogastric plexus with hypogastric nerves, the pelvic splanchnic nerves and the inferior hypogastric (pelvic) plexus; the pudendal nerve [5, 6, 14]. The autonomic system, especially the parasympathetic plexus, creates synapses with the myenteric plexus of the rectum and anal canal [5]. Pelvic musculature has voluntary and involuntary control. The pelvic floor can be induced to contract consciously, such as during physiotherapy, or to act automatically, such as during arm movements, breathing, coughing, lower limbs and trunk muscles [15-18]. Neural centers for such automatic synergies are little understood. Pelvic musculature is represented in the medial wall of the precentral gyrus, where it is triggered by both voluntary movements and movements of other muscles of the pelvis; this means that there is a pre-activation of the premotory cortex, but this activation only reaches the conclusion if the upper centers ensure that the contraction is necessary [17]. Another area involved in involuntary movements of the pelvic floor associated with breathing, involving the respiratory diaphragm, the abdominal wall and the tongue (during inspiration retrudes as it expires with the exhalation), is the retroambiguous nucleus of the medulla oblongata [19, 20]. The neurological mechanisms involved in that are not clear.

3. Functions and Malfunctions

A healthy pelvic floor shows a slightly cephalic position of the perineal area if compared to the ischiatic tuberosis at visual inspection [21]. At rest it shows a cupuliform attitude resembling the respiratory diaphragm muscle; when contracted it ascends anterocranially (towards the pubes and the large pelvis) while, on the contrary, when released, it moves through a posterior-caudal direction (towards the sacral bone and the ischiatic bones) with a displacement of about 3 centimeters [3-5, 22-25]. In this action, the coccyx undergoes a ventral-cranial and dorsal-caudal motion [5, 22, 24, 25]. Some parameters can be calculated at magnetic resonance to verify its position. The pubococcygien line is measured between the pubic symphysis and the coccyx, while the anus-rectal angle is considered as the space between the posterior margin of the rectum and the line running through the central axis of the anal canal [3, 4]. In the healthy patients, the base of the bladder, the upper third of the vagina and the peritoneal cavity must be on or adjacent to the pubococcygien line, with the anus-rectal angles cranial or adjacent to the previously mentioned line; when the pelvic floor contracts, the viscera ascend and the angle becomes acute [3-5]. The pelvic floor supports the male and female viscera and the rectum, allowing for optimal contraction [4, 24]. With contraction and relaxation, the musculature creates a series of pressures that assist the viscera in their functions; a proper contraction of the pelvic floor allows sexual function and sexual activity [23]. When the respiratory diaphragm is lowered by inhalation, the pelvic diaphragm undergoes a caudal motion, this allowing the respiratory action to encounter less resistance; the opposite movement occurs during exhalation [19, 25]. The pelvic diaphragm influences the breathing with its contractile status. Another important function of the pelvic floor is the postural one, again together with the respiratory diaphragm and abdominal muscles. To allow twist movements of the trunk, to stand up or sit or simply to stay in orthostatism, coughing and sneezing, muscle groups able to hold the thoracolumbar and lumbosacral column must be activated; all the abdominal muscles (respiratory diaphragm, transverse and oblique), the pelvic floor (and other connected muscles such as obturators, piriformis, adductors), and the large gluteus simultaneously activate [17, 19, 23, 25-27]. There is myofascial continuity among the muscular mentioned districts. The diaphragm muscle, through the transverse muscle and the fascia trasversalis anteriorly, and the thoraco-lumbar fascia posteriorly, merges with the anterior margin of the pelvic floor (pubis) and the posterior one (sacrum) [19, 26]. The rectum abdominis and its fascial system merges at the level of pubic symphysis with the adductor muscles, both activated by the contraction of the pelvic floor; the pelvic floor is in anatomical continuity with the large gluteus, also involved in the pelvic contractions [28, 29]. Pelvic floor contractions allow the distribution of loads from the trunk and upper limbs to the lower limbs and vice versa during walking and in orthostatism, thanks to the mentioned anatomical connections [27, 28, 30, 31]. The same foot position is affected by the muscular tension of the pelvic floor, which affects the tone of the rotator muscles of the hip; the pelvic floor tension will affect the behavior of the adjacent contractile districts [23, 32]. (see table 3)

Table 3. *Pelvic floor function.*

Support for the pelvic viscera
Sexual function and coitus
Breathing
Posture maintenance
Transmission of tensions from the limbs to the trunk and vice versa
Deambulation

A deficiency in pelvic floor muscle tension or an electrical abnormality of these districts will cause many disorders and pathologies, including visceral prolapse and urinary incontinence, fecal constipation. It is estimated that pelvic floor muscle disorders will increase by 35% over the next two decades, to an average of around 1.6 million visits per year for 2030 [23]. Pathogenesis is highly variable and multifactorial: birth injury; elderly; obesity; chronic pathological conditions that cause an increase in abdominal pressure; previous surgical interventions in the pelvic area [3]. The major problems encountered in the anterior compartment include: dysuria; urinary frequency; cystocele; urinary incontinence. Central compartmental disorders are usually represented by vaginal or uterine prolapse [3]. Changes in the posterior region cause: pelvic and/or anal pain; constipation; rectal prolapse; fecal incontinence [2, 3]. Peritoneal compartment disorders can lead to: dyspareunia; constipation and low back pain due to alterations in rectum and sigma [2]. (see table 4).

Table 4. *Pelvic floor dysfunctions.*

Anterior compartment
Dysuria
Pollakiuria
Cystocele
Urinary incontinence
Myofascial pelvic pain
Medium compartment
Vaginal or uterine prolapse
Myofascial pelvic pain
Posterior compartment
Pelvic pain and/or anal
Constipation
Rectal prolapse
Fecal incontinence
Myofascial pelvic pain
Peritoneal compartment
Dyspareunia
Constipation
Low back pain
Myofascial pelvic pain

Pelvic floor issues may involve a few districts or all of them [2, 3]. The stress urinary incontinence (SUI), the most common of incontinence forms, occurs in the presence of stimuli such as cough or sneezing, conditions where the increased pressure inside the pelvic cavity exceeds the muscular control ability [27]. SUI affects about 26% of women between 30 and 59 years, with a peak in 40-49 years [27]. The causes do not only affect the levator ani, but its interaction with the adjacent muscles and joints: there is evidence that the pelvic floor acts in opposition to the respiratory diaphragm; the pelvic floor cannot properly distribute the tensions produced during trunk/ limb movements; there is a decreased electrical activity and/or electrical dissipation in the use of the muscles; a postural alteration of the lumbar spine alters the electrical behavior of the floor [26, 27, 30]. The lack of pelvic tilt for lumbar hypolordosis (the pelvis is inclined posteriorly, the sacrum is displaced anteriorly in flexion and the pubis oriented in anterior-inferior direction) causes an increase in the vertical load to the pelvic muscles, stretching the muscle fibers each time you walk or run; this condition will progressively lead to the weakness of the levator ani [25, 27]. In healthy people with hypolordosis, visceral pressures in the pelvic cavity in orthostatism increase, as there is an increase in the electromyographic spectrum of the elevator; it is thought that these events have a negative effect on continence in subjects with pelvic floor disorders [25, 26]. SUI in men is related to previous surgical prostatectomy [33]. The prolapse of the pelvic organs caused by the weakness of the pelvic floor muscles is a problem affecting 30-50% of women, potentially leading to urinary and rectal problems, as well as disturbances to the sexual sphere [34, 35]. We do not have accurate data on rectal prolapse in men [36]. Constipation affects about 27% of the population, especially women, whose main causes can be related to the pelvic floor, to a paradoxical contraction of the musculature, a general muscular weakness and incomplete relaxation after contraction [3, 5, 37]. Fecal accumulation in the rectum could lead to urinary and / or visceral prolapse [27]. Another problem related to the pelvic floor is pain. Several disfunctions including interstitial cystitis/bladder pain syndrome, chronic prostatitis, provoked vestibulodynia, chronic vulvar pain disorder can present with several symptoms, but always with a single common denominator: painful muscle dysfunction (spasm, trigger point, hypotonia) [23, 38, 39]. Myofascial pelvic pain (MPP) affects about 14-23% of women, but these data are underestimated, and not accurate or what regards males; MPP presents with pain arising from muscular and connective tissue, and can present as a single symptom or as a series of urological, gynecological and colorectal symptoms [21, 40]. The source of pain not only involves the pelvic floor, the urogenital diaphragm and the perineal membrane, but also some myofascial structures closely related, such as the piriformis and the internal obturator muscle; the symptoms may radiate from an initial area, affecting the gluteus, the abdomen, lumbar spine, chest, pelvis and lower limbs [21]. Muscle may create conditions such as the presence of trigger points (TPs). The causes are different and sometimes concomitant, such as a trauma or injury, the presence of a scar, chronically altered posture, metabolic dysfunctions and food deficiencies, and psychological stress [21, 40]. A constant change in the length of the muscle fibers can lead to an altered circulation, hypoperfusion and ischemia, with the formation of TPs, even latent for many years [21]. The pain arises when the TP is stimulated, for example for a movement or for a body function, when a myofascial area is stretched or compressed [21]. A constant stimulus of the nociceptive system forces a plastic change of the nervous structures, either peripheral or central, forming what is called a central sensitization [41]. This event results in an increased response of medullary neurons (allodynia), persisting also when the causal stimulus stops (hyperalgesia), causing an altered response from other non-injured tissues, resulting in pain (secondary hyperalgesia) [41]. The same connective tissue can be a source of pain, becoming less metabolically active and less adaptable to mechanical changes [23]. The connective tissue can directly convey pain signals; in fact, it contains nociceptors that can translate mechanical stimuli into pain information; if there are nonphysiological mechanical stimuli, the proprioceptors can turn into nociceptors [9, 10]. Reduced sliding of the various layers limits the functionality of the endocannabinoid system. There is a close relationship between the endocannabinoid or endorphin system and the fibroblasts [9, 10]. The cannabinoid receptor, or CB1 (is the most common neuroreceptor), is mainly housed in the nervous system, but it can be found in the fascial system and in the fibroblasts as well, particularly near the neuromuscular junction. This relationship is believed to better manage any inflammation and pain information originating in the fascial tissue, as the fascia undergoes continuous remodeling during the day [9, 10]. It is hypothesized that the axoplasmic flow originating in the dorsal ganglionic roots carries some molecules to the distal nerve endings, in an attempt to reduce pain information deriving from the nociceptors in the fascial continuum, such as CB1 [9, 10]. Normally, CB1 closes Na+ and opens K+ channels, hyperpolarizing the nociceptor, preventing peripheral sensitization and pain [3]. If there is a mechanical barrier owing to a reduction of the fascial sliding, the axoplasmic flow will be hindered, with consequent onset of hyperalgia, because CB1 can not be transported in the distal nerve [9, 10]. The fascial system is also important to act directly on the tension of the contractile tissue. Proprioceptors located in connective tissue (ligaments) activated by stretching, due to medullary reflex, are able to stimulate muscle contraction useful to suppress the tension created by the fascial fibers, ensuring the proper degree of tension and release of the muscle [1]. An alteration in the muscle tone can cause dysfunction of the pelvic joints that, and even this condition can cause pelvic pain, as the same joints become a source of pain; a vicious circle is created where the structures used to correctly transfer the loads during movement fail in their functions, leading to further pain and symptoms [27, 31, 41-43]. The pelvic floor with an altered status may trigger unspecific symptoms such as respiratory disorders, low back pain, sacroiliac joint pain, pelvic girdle pain [27, 31, 42, 43]. The abnormal tension of the pelvic floor muscle can cause the same neurological compression / trapping syndromes that can be easily detected for the upper and lower limbs, such as compressing or preventing the nerves' sliding; an example is pudendal nerve syndrome or Alcock's syndrome, often negatively affected by muscular hypertone [44-46]. The pudendal nerve (S2-S4) passes into the Alcock channel, between the sacrospinous and sacrotuberous ligament at the level of the ischiatic spine, affecting the fascia of internal obturator muscle; its entrapment will cause unilateral genital pain to the genital area, anus, and pelvic area [47]. A general manual and instrumental medical evaluation can be find in literature. With regard to the manual examination there is still no inspection technique involving all the components of the pelvic floor. The evaluation begins with anamnestic interview and visual observation of any non-physiological change; the active movements of the lower limb, the lumbar spine, and the presence of symptoms are observed [48]. The patient's posture, orthostatism and walking are observed, as an altered body alignment could cause compensatory stress to the pelvic floor [31]. The current manual evaluation focuses on measuring the ability to contract pelvic muscle, quantifying its strength, and looking for TPs [24]. The external tissues of the abdomen, the thigh, the gluteus, as well as the perineal area, are tested to verify the presence of TPs; intravaginal or rectal palpation is also performed to highlight the presence of sore areas; with the internal evaluation one can require to contract muscle, in order to understand its ability to control and pain presence [21, 23, 38, 40, 49, 50]. To explore the presence of TPs and painful areas with intravaginal palpation, the Q-tip test is used; the test assigns the value of the present pain, with a minimum of zero for complete absence of pain, and a maximum of 10 to report the worst pain as possible [23]. To the muscle strength actively evaluated can be given a score of 0 to 5, with reference to the Chirarelli scale: zero corresponds the lack of contraction, while the maximum value of 5 indicates a physiological function of the musculature [49]. One study proposes to evaluate the coccyx externally, placing the palm of the hand on the coccygien area, with the sitting sit and in lateral decubitus; the patient is asked to contract the pelvic floor, following the bone movement through palpation [22]. The muscular strength of the pelvic floor can also be measured with intravaginal instruments such as manometers and dynamometers; the first measures the strength expressed in millimeters of mercury, while the second instrument calculates it in newtons [24, 50]. Differential tests are also performed to evaluate the presence of pain in the sacroiliac joint (SIJ), such as the Active Straight Leg Raise Test (ASLRT). ASLRT is the most important test to understand the presence of pain at SIJ and to differentiate joint dysfunction of the lumbar region and hip; it is also useful to highlight a potential dislocation of the SIJ [31, 43, 49, 51]. Intravaginal cones are intravaginal instruments that can give information on the pelvic floor contraction, and feedback on response to therapy [24]. They have different shapes and sizes, with a dual purpose: to evaluate and help the patients to understand how they can work on their own muscles [24]. Other medical instruments used for diagnosis are intravaginal or intracranial ultrasound, or sovrapubic and perineal ultrasound, depending on the physician's decision [24, 50]. Ultrasound can produce two-dimensional or three-dimensional images, giving information on muscular and visceral behavior [5]. Electromyography (EMG) provides information on how the pelvic floor contraction, either voluntary or not, behaves; the electrodes can be superficial or intramuscular, and this depend on the area to be evaluated [24]. These can placed on the surface for more general information, while more painful investigations are needed for deeper or more specific muscle areas [24]. The use of the EMG and proper reading of the spectrum depend on the position of the electrodes and the posture of the patient to be examined [26]. EMG is less intense in the supine position and with bent legs than in sitting position and in orthostatism

[26]. The preferred diagnostic tool is magnetic resonance imaging (MRI). MRI can provide very precise information on what is happening in the examined pelvic area (muscular, visceral and connective) with the ability to obtain real-time measurements of how the pelvic floor is positioned and how it contracts, how the viscera behave, without discomfort for the patient [2, 4, 5]. The relaxed pelvic floor descends approximately 3 cm under the previously mentioned pubococcigien line in healthy subjects [4]. The choice of the use of this instrument will depend on the physician's experience [3]. Computed Tomography (CT) can provide dynamic information on pelvic floor changes during contraction and defecation but it represents a second choice compared to MRI for the presence of rays in the examination; anyway, in all cases the physician decides how to orient the diagnostic procedure based on the subjective necessity of the patient [5].

4. Usual Evaluation

In literature there are a lot of papers dealing with manual physiotherapy for the pelvic floor, visceral prolapse and incontinence, pelvic pain and dysgeusia, constipation [22, 24, 50, 52, 53]. There is no gold standard path in the rehabilitation of the pelvic floor in presence of dysfunctions. Several authors, in case of patients with incontinence or visceral prolapsed, suggest to increase the strength of the levator ani muscles by increasing muscle contractions and time of contraction (in seconds, from 5 to 10); at the same time, it is vital to increase the patient's proprioception, for example through sound, visual or electrical or manual intravisceral (vaginal or rectal) biofeedbacks [50, 54-57]. Contractions can also be made in different postures (supine, prone, standing), by contracting the pelvic and involving the adjacent musculature (large gluteus, piriformis, obturators) [29]. Depending on the patient's need, relaxation techniques of the pelvic floor cab ne used, especially in the case of chronic myopathic and visceral pelvic pain. Stretching exercises can be performed for the levator ani muscle, sometimes with vaginal dilators, using contractions followed by prolonged relaxation of the pelvic muscle [21, 38, 40, 49]. Another approach to improve the muscle relaxation is the research and treatment of TPs, external and internal to the pelvic floor, and in the adjacent area (abdomen and lower limbs), either through ischemic compressions addressed to the area, or with gentle myofascial treatment [21, 23, 38-40, 49]. Only recently, a study combined the restoration of the pelvic floor control with abdominal muscles and breathing, particularly for patients with urinary incontinence, demonstrating an improvement in symptoms and quality of life [18]. Other manual approaches such as the osteopathic and chiropractic ones are less common in the literature. A study on healthy women evaluated the muscular tone response of the pelvic floor by recording intravaginal pressure levels, with osteopathic manipulation addressed to the sacrum (HVLA-high -velocity and low-amplitude); it was noted that basal tension after manipulation increased [58].

An article of chiropractic applications highlighted the results of some case reports (21 cases) on the effect of spinal manipulations for conservative treatment in urinary incontinence, with different patient related techniques; according to the authors, benefits were in some cases minimal and in other significant, depending on the patient's response to treatment [59]. If conservative treatment for pelvic floor dysfunction is ineffective, surgery and pharmacology are used with different approaches depending on the involved anatomical area, the surgeon's habit and the subjective necessity of the patient [60, 61]. The results for incontinence and prolapse would seem satisfactory [60, 61]. Patients are encouraged to follow a pelvic floor rehabilitation path after surgery to improve surgical results [62]. However, post-surgical major risks are the recurrence of the primary symptom, such as incontinence and prolapse, and the advent of chronic pelvic pain, whose reasons are not clear [63-65].

5. Evaluation Proposal

There is no conservative working protocol considered as gold standard; the existing ones are never specific or do not fully involve all the components of the pelvic floor. A complete muscular skeletal manual evaluation is currently missing, hence a complete therapeutic conservative iter cannot be set up, and the results cannot be properly evaluated. We propose a hypothesis of manual evaluation protocol to know precisely what is the area or anatomical areas needing more therapeutic attention. Probably, knowing in detail how to organize the conservative rehabilitation scheme, the results of the non-surgical approach could be further improved. Palpation is an important tool for assessing, classifying and differentiating, with diagnostic potential; the fingers have a tactile sensitivity are able to discern objects measured in micron [66-69]. The palpatory examination is able to depict the joints' position and to detect abnormal articular movements, tissue abnormalities (temperature, tone, hardness, and other) from the surface to the depth of the various layers, and locate the painful anatomical area [68, 70, 71]. The proposed evaluation does not take into account the classical intravaginal or intrarectal palpation, as the aim of the manual exam is to broaden the possibility to evaluate the pelvic floor also for those manual professionals who are not able to perform invasive palpation, or simply to those doctors who are not willing to test genital areas. It is appropriate to evaluate the pelvic floor only externally [21]. The evaluation protocol consists of three phases, with a total duration of about 20 minutes: supine patient, on the side and prone.

The first phase is performed with the patient supine, first evaluating the area of the pubic joint. Pubic joint is a key area of the pelvic floor; is a point of insertion and origin for abdominal and lower limb muscles, respectively, as previously described. During the contraction of the levator ani, the pubis acts as a fixed point to perform an anterior traction on the pelvic muscular dome as it rises cranially. The pubic joint allows the pelvic muscle dome to find its positional identity. The pubic symphysis follows the movements and pressures of the lower limbs and the pelvis; it is a mobile structure able to interacting in synergy with other pelvic mechanics, with a maximum movement of about 4 millimeters (internal induction/rotation, abduction /external rotation) [28, 72]. The joint is innervated by pudendal and genitofemoral nerves, from the branches of the ilioipogastric and ilioinguinal nerves; it can be a source of pain, and a cause of urinary pathologies for somato-visceral reflexes [28, 73]. A mechanical dysfunction of the pubic symphysis can also cause a mechanical disorder of one or both iliac wings, with potential further musculoskeletal disorders of the pelvic floor [28, 73]. The operator, standing side to the patient, palpates the pubic tubercles with the fingers, to verify the presence of pain and TPs, and the quality of the tissue [42]. (see Figure 1).

Figure 1. *The pubic tubercles.*

To test the mobility and the presence of induced pain, the patient is asked to bend the knees putting the feet on the cot; the operator puts his forearm between the patient's knees, asking him to close his legs. (see Figure 2).

Figure 2. *To test the mobility and the presence of induced pain of pubic tuberles.*

The tension produced in the area of the pubic symphysis reveals whether there is articular instability or restriction of mobility [74]. Remaining in the pubic area, the local tissue is palpated for the presence of TPs. The patient is asked to stretch the legs while the operator tests the inguinal ligament (pubic tuberculosis and anterior-upper iliac spine). (see Figure 3).

Figure 3. *To test the inguinal ligament.*

Superiorly it is composed of the fibers of the internal oblique and transverse muscles of the abdomen, and the aponeurosis of the same muscles; below, it continues with the fascial system of the large psoas and iliac muscles; in the anterior portion it lies on the aponeurosis of the external oblique muscle, while the posterior margin is in contact with the transversalis fascia [75]. It is a fascial structure affected by the muscular tension of the muscles of the abdominal wall; is innervated by the ilioinguinal nerve, and may have direct relation with the tendon of the long adductor muscle [28, 76]. Then it becomes an active structure interacting with the external tensions. The origin and the insertion are palpated, and the tissue along its course is manually tested. The next step is the palpation of the obturator nerve. A peripheral superficial nerve can be palpated, evaluated, and treated [46]. The obturator nerve origins from the anterior segments of L2 up to L4, both motor and sensitive; motor for the adductor muscles (long and short adductor, gracilis, external obturator and large adductor), and sensitive for the region corresponding to the infero-medial region of the thigh, hip and knee [77, 78]. We can palpate the nerve in two points. The first one is near to the pubic tuberculosis. The tubercle and the upper branch of pubic bone should be searched, while the inguinal ligament is immediately above; once the tubercle has been detected, it is necessary to descend a few centimeters (one-two fingers) [79]. One finger is placed on the pectineus muscle; the obturator nerve is located immediately below [79]. (see Figure 4).

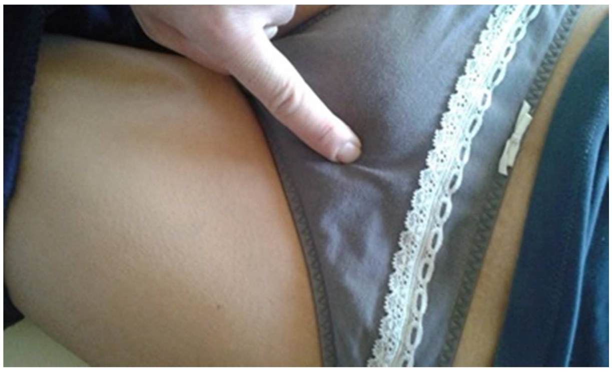

Figure 4. *The obturator nerve first point.*

Another point to be evaluated is inside the long adductor muscle; it can be searched in the proximal third of the muscle, depicting an imaginary line from pubic tubercle to the knee [79]. (see Figure 5).

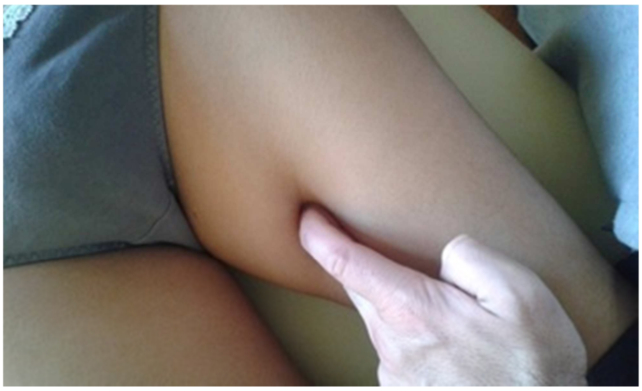

Figure 5. *The obturator nerve second point.*

By staying in the third proximal area of the thigh and placing the palm of the hand on the adductor muscle, muscle strength is evaluated by asking the patient to push against the operator's hand; some pubic pains can be also detected [28]. (see Figure 6).

Figure 6. *To test adductor muscle.*

To test the tone and strength balance of the hip rotator muscles, the operator stands at the patient's feet, placing the palms of the hands on each plant of the foot; resisting to the movements, he asks the patient to move his feet outwards and inwards, always with his legs stretched, without bending his back and keeping his ankle in a neutral position [40]. (see Figure 7).

Figure 7. *To test the tone and strength of the hip rotator muscles.*

Assessing the strength of the muscles involved in hip movement (pelvis / lower limb) is crucial to understand pelvic behavior [32]. For a passive evaluation, the operator grabs the ankles of the supine patient, with the legs always extended, and makes internal and external rotations, testing the ligament and tendon component of the coxo-femoral complex; lastly, slight tractions towards the operator can be perform, to verify whether the resistance to this action is the same on both sides. (see Figure 8).

Figure 8. *Passive evaluation of the hip rotator muscles.*

Always with the supine patient but with the knees bent, feet in support, the pelvic floor can be palpated externally. The pelvic floor must be imaged as a watch dial. The 12 o'clock refers to the pubis, the clitoris and the urethra; 1 and the 11 correspond to the ischiocavernous muscles; 2 and 10 refer to the bulbospongiosus muscles of the superficial perineal layer (for urethra contraction, clitoral or penile erection); 3 and 9 correspond the transverse perineal transverse muscles; on the back, 4-5 and 7-8 correspond to the front and back muscle masses of the remaining contractile districts of the levator ani; 6 corresponds to the coccyx [21]. (see Figure 9).

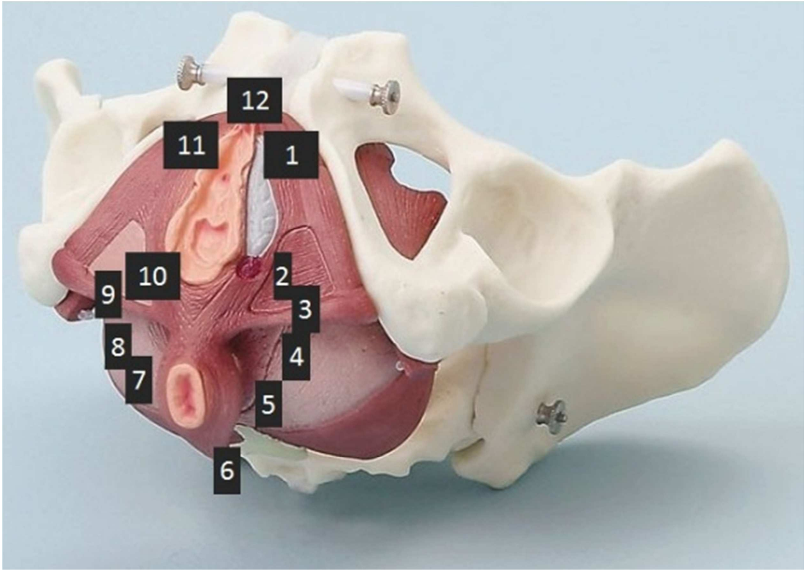

Figure 9. *The pelvic floor must be imaged as a watch dial.*

Painful areas and TPS are indicated with this method. The function of the pelvic floor can be also evaluated by palpating it externally, relating it to the movements of the respiratory diaphragm muscle. We know that if an inspiration or expiration occurs, the respiratory diaphragm lowers and rises respectively [19, 20, 74]. Unilaterally or bilaterally, with two hands, the operator places his fingers on points 1 to 5, asking the patient to deeply inhale and exhale; the examiner simultaneously palpates as the pelvic floor moves. When the muscles push against the fingers, it means that it is in descent, while the opposite happens when it is in the elevation phase. (see Figure 10).

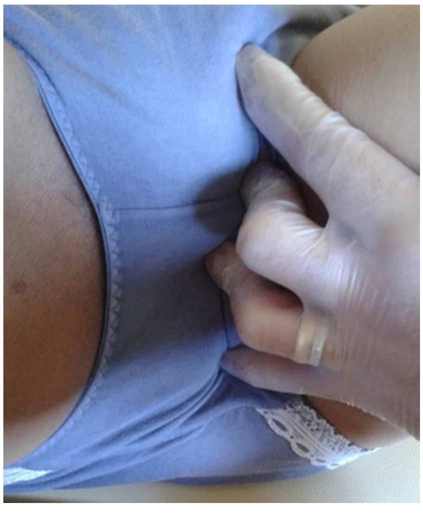

Figure 10. *The movements of the respiratory diaphragm muscle.*

The subsequent evaluation concerns the pudendal nerve. The pudendal nerve (S2-S4) is a complex structure made of motor, sensory and autonomic fibers [80]. It runs behind the sacrospinous ligament, medially to the ischiatic spine; then it runs through the gluteal region between the sacrotuberous and sacrospinous ligaments toward the inner surface of the internal obturator muscle [81]. It runs ventrally, medially and then caudally through the lower portion of the ischiatic foramen, into the gap between the piriformis muscle and the ischiococcygien muscle [80]. It enters the pudendal channel before ending in the perineum. Before or immediately outside the Alcock channel, the pudendal nerve divides into some terminal branches: the lower rectal nerve; the deep and superficial perineal nerve; the dorsal nerve of the clitoris or the penis [81]. The pudendal nerve has little mobility between the sacral ligaments and the puendal channel; in these sites non-physiological traction are easy to happen, such as in birth or injury to the pelvic floor, or surgery in the pelvic area [80]. When the levator ani ascends, it can squeeze the nerve, producing pain [81]. Symptoms are usually growing during the day; the woman might complain the sensation of an "object" inside the vagina [81]. The simplest point to palpate the pudendal nerve, assessing its course and the presence of pain, without employing invasive approaches, is at the outlet of the channel of Alcock, medially to the ischiatic tuberosity; to be sure to be in the exact area, you can help palpating the pudendal artery [82]. The operator outlines the ischiatic tuberosity until he perceives the artery and nerve pulsation (like a small rope); small taps can be given for a Tinel test, or small transverse movements can be performed to ensure there is no movement restriction [40]. (see Figure 11, 12).

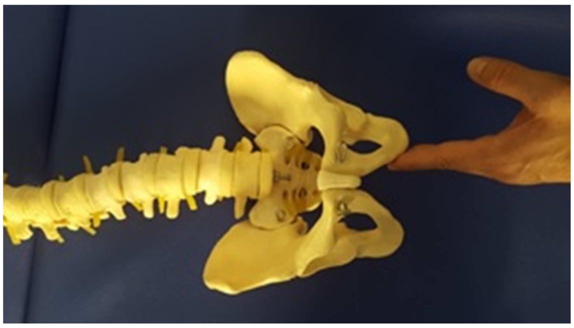

Figure 11. *To palpate the pudendal nerve. Example with the anatomical model.*

Figure 12. *To palpate the pudendal nerve.*

Another issue to be tested is the mobility or movement restriction between the sacrum base and L5. The sacrum base and the last lumbar vertebrae constitute the lumbosacral complex, influencing the arthrokinematics of the spine and posture in general; a limitation or over-movement of this joint will result in an altered movement of the iliac bones, coccyx and most probably an abnormal muscle tension of the levator ani [83]. With the patient supine the palm of the hand is placed under the sacral bone with the fingers placed in the base of the sacrum, while with the other hand the last spinous process of L5 is searched, placing one finger caudally to the spine. The hand holding the sacrum provides a slight traction towards the feet, while the finger under the spinous process of L5 holds the position; only a minimal manual force is required, without bothering the patient, to perceive any movement restriction [83, 84]. (see Figure 13).

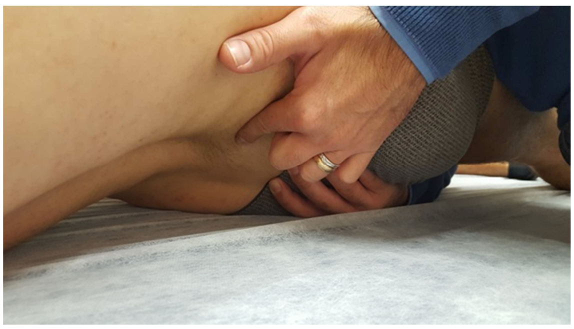

Figure 13. *The mobility or movement restriction between the sacrum base and L5.*

The following evaluation concerns the sacral-iliac articulation. The iliac bone and the sacrum have close relationship with the pelvic floor, and their ability to collaborate will affect not only the muscular tension of the levator ani, but also the dynamics of distribution of the different tensions between the trunk and the lower limbs [43, 51]. It is innervated by S1-S4 with myelinated and not myelinated fibers, involving mechanic receptors (simil-paciniform or not); this means that it will be a site for proprioceptive and nociceptive information [85, 86]. It is a diarthrosis with synovia, able to undergo movements (1-4 degrees rotation and 1-8 millimeters of translation); it may be palpated below and medially to the posterosuperior iliac spine (PSIS), as radiographically demonstrated [42, 86, 87]. The operator places the palm under the sacrum of the patient, while with the other hand he grabs the PSIS (at S2 level), which is and easy-to-do operation [88]. The hand holding the PSIS slightly moves outwards and transversally the iliac bone, while the hand under the sacrum ensures that the bone remains unmoved; the operation is repeated on the other side, recording potential differences in movement restriction or hypermobility. (see Figure 14).

Figure 14. *To test the sacral-iliac articulation.*

Moving to the next evaluation, the patient is asked to sit on the side. The operator stands behind the patient, who has stretched legs. The leg is lifted up, not resting on the cot, to place the hands on the points of the pelvic floor described above, always asking for deep breaths. This different position serves to detect the cranio-caudal movement of the pelvic floor with tensions different from those of the supine position (gravity, leg weight, different visceral position), trying to understand if there are any obvious differences and to facilitate the operator in finding a position more consistent with its ability of palpation. (see Figure 15).

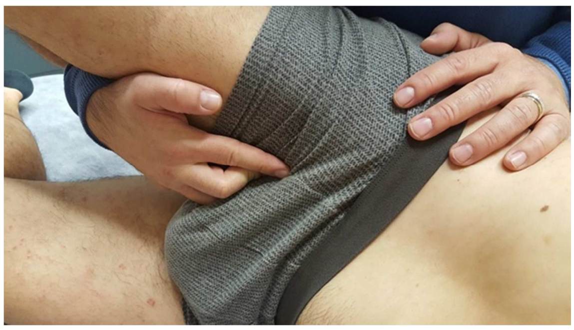

Figure 15. *To detect the cranio-caudal movement of the pelvic floor.*

The following assessment relates to the ileolumbar ligament.

Its tension influences L5-S1 and the sacro-iliac joint, giving stability, especially on the sagittal plane; it stretches from the apex of the transverse process of L5 to the ventrocranial area of the sacropelvic surface of the iliac crest [89]. Pain is tested, as there is a dysfunction of this ligament, it can be a source of pain (it contains mechanoreceptors and nociceptors) and can alter the sacral, iliac and lumbar arthro-kinematics [89-93]. The operator is in front of the patient, asking him to move back to the opposite edge of the cot, positioning obliquely, so that he can move his straight leg outside the cot; the leg of the side resting on the bed is bent. The operator puts a hand on the L5 area, while the other hand moves the leg down, and at the same time controls the downhill. (see Figure 16).

Figure 16. *Assessment to the ileolumbar ligament.*

This produces stretching and stimulate the ligament receptors, respecting its anatomy [92, 93]. The operator stands behind the patient to perform another evaluation. One hand is placed medially to the area of the ischiatic tuberosity, while the other grabs the surface of the iliac crest, as if to take the entire iliac bone; it is slightly moved towards the ceiling [74]. (see Figure 17).

Figure 17. *To test iliac bone.*

With this maneuver, the soft structures of the sacro-iliac and pubic system are placed in tension, as well as the muscular apparatus of the levator ani, discovering painful areas and evaluating motion restrictions or hypobility. It is also possible to perceive whether the iliac bone is rotated in front or back, depending on the force vectors present; if the iliac bone is rotated anteriorly, the sacroiliac joint will be in a painful state of because its ligamentous structures will be placed in tension [51]. By contracting the soft ligamentous structures, an articular dysfunction of the pubic symphysis and sacroiliac joint may be highlighted, as they influence each other [94]. For the evaluation of the coccyx, the operator stands in front of the patient, who has his knees bent. The operator locates the coccyx with his hand, performing lateral translation, testing the mobility and the possible appearance of pain. (see Figure 18).

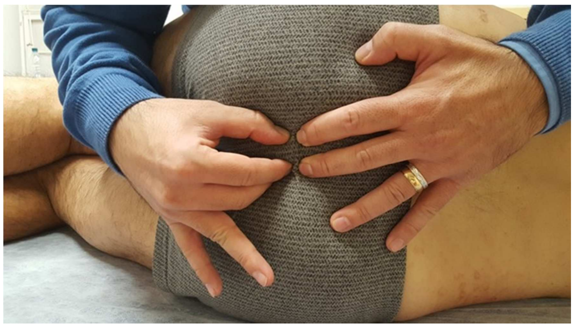

Figure 18. *To test the coccyx.*

Coccyx is an important point of muscular and legamentous support: levator ani muscle; fibers of the large gluteus; sacrospinous and sacrotuberous ligaments; anococcygien ligament [95]. Its mechanical balance is important for the muscular function, being imperative to control its mobility; a spasm of the levator ani can limit its biomechanics [82, 95]. Its movements lead to a good visceral function; to test the proper mobility of the coccyx, the lateral decubitus position is good [96]. In the previously mentioned position, the operator identifies the coccyx and asks the patient for deep inspiration and exhalation; During inspiration the respiratory diaphragm goes down together with the pelvic floor, leading the coccyx to have a dorsal-caudal movement of extension, while the opposite action occurs during exhalation [19, 20, 22]. Normally, the movements of flexion-extension occur for a maximum of 8.1mm [96]. In the third phase, the patient has to be prone. The operator puts his hands on the sacral bone, one hand over the other; Solicitations with a vertical vector or spring test are performed to evaluate the tension of the sacrum [74, 83, 84]. (see Figure 19).

Figure 19. *To evaluate the tension of the sacrum.*

The expert operator is able to detect whether there is an articular problem (dry block to the traction performed), or a dysfunction of soft tissues such as muscles and ligaments (if the push towards the cot is slowed down as a toothed wheel) [74, 83, 84]. Always in the sacral area, and also involving the distal lumbar and posterior iliac areas, TPs of the thoracolumbar fascia are searched. We know that fascial tissue can contract and produce painful areas (it contains many free receptors, encapsulated or not, and receptors of Pacini and Ruffini), spasms, altering the tissue density, and becoming a source of pain [9, 41, 97]. The thoracolumbar fascia has direct connections with the transversalis fascia and transverse muscle, oblique muscles, large gluteus, all sacral and coccyx area, sacroiliac joint, sacrotuberous ligament, femoral biceps and piriform muscle; its dysfunction will create alterations to all the connected structures [86, 98]. A major muscular portion to be evaluated is the large gluteus muscle. The large gluteus is part of the levator ani muscle, influences the sacroiliac joint and the distribution of the loads between the trunk and the lower limbs, thereby contributing to the pressure of the pelvic floor [99]. It is necessary to palpate the muscle on the surface and deeply in search of any TPs, as well as testing its force manually in its various components, in particular the extension and the extrarotation of the lower limb [100]. The piriformis (from S2 to S4 to the great trochanter) is in myofascial continuity with the obturator muscles and with the levator ani muscle; it has a close relationship with the large gluteus and the pudendal nerve [101]. It is a deep muscular belly located under the large gluteus; its actions are mainly related to the external rotation of the hip and extension (it has a secondary role as an abductor) [101]. The connection between the levator ani and the piriformis muscle is found both in fetal and in adult life [102, 103]. As for the large gluteus, it is necessary to look for any TPs, but with a greater pression of the operator's fingers in the muscle. We need to test its strength against resistance: the operator bends the patient's knee, places his free hand toward the piriformis area, pulls the lower limb and rotates it externally (producing a hip intrarotation), asking the patient to perform an opposite action, while the operator maintains the position [74]. (see Figure 20).

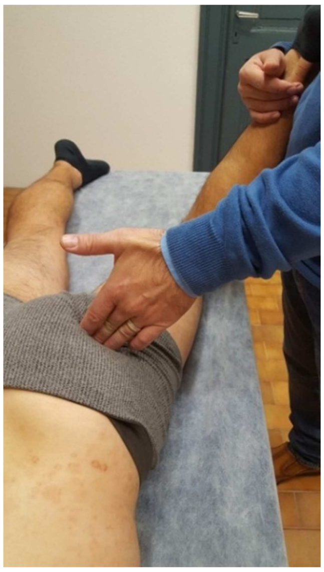

Figure 20. *To test piriform muscle.*

In this way, the operator does not only does evaluate the strength but also induces a stretch of the piriformis resulting, in the presence of TPs or spasms, in pain [104]. The long dorsal sacroiliac ligament can be palpated in the caudal area of the posterosuperior spine, with an average width of about 15 to 30 millimeters; it appears to the touch as a very dense fascial cord, almost a bone tissue; the greater its density, the greater its dysfunction [42]. (see Figure 21).

Figure 21. *To test the long dorsal sacroiliac ligament.*

In its course it reaches the sacral lateral transverse tubercles, from the second to the fourth segment of the sacral bone, covering the sacro-iliac joint; it has nociceptive afferents and is penetrated by the cluneals central nerves (dorsal sacral branches) [105]. Along with the sacrotuberous ligament, it controls the movements of the sacral bone with respect to the iliac bone; its connections affect the long head of the femoral biceps, the sacrospinous and sacrotuberous ligament, the levator ani (ischiococcigeo), the aponeurosis of the spinal erectors muscles and the thoracolumbar fascia [106, 107].

The pelvic floor can be palpated even with the patient prone, especially in the posterior portion. The operator places the fingers of the hand (as to cut), adjacent to the ischiatic tuberosity; the patient's is asked to collaborate with inspiration and forced exhalation, in order to better evaluate the reflex motion of the pelvic floor. (see Figure 22, 23).

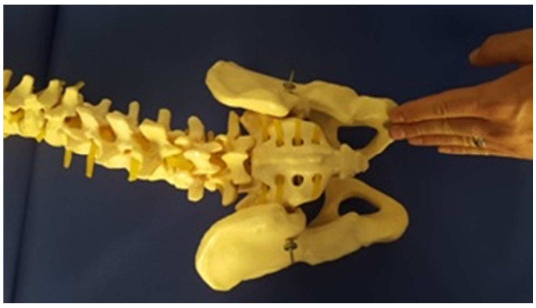

Figure 22. *To test pelvic floor in prone position. Example with the anatomical model.*

Figure 23. *To test pelvic floor in prone position.*

Tables 5 and 6 summarize all the evaluation steps described here. (see table 5 and 6).

Table 5. *Manual assessment: Supine and lying on the side.*

Supine position
Symphysis pubis
Suprapubic area for TPs
Ilioinguinal ligament
Obturator nerve
Adductor muscle strength
Rotator muscles strength of the hip
Pelvic floor muscles
Pudendal nerve
Sacral base-L5
Sacroiliac joint
Lying on the side
Pelvic floor muscles
Iliolumbar ligament
Iliac bone
Coccyx

Table 6. *Manual assessment: Prone position.*

Prone position
Spring test sacrum
TPs Thoracolumbar fascia
Gluteal muscle
Piriformis muscle
Long dorsal sacroiliac ligament
Pelvic floor muscles

Once the major anatomical area has been recorded by manual evaluation, we will focus on specific orthopedic and neurological tests to extrapolate more useful information for diagnosis or rehabilitation decisions. Knowing whether the tissue or joint are in hypo or hypermobility, rehabilitation choices might be more focused on the patient's need.

6. Conclusions

The focus of the article is the proposal of a manual evaluation of musculoskeletal structures forming the pelvic floor as it currently lacks a complete palpatory examination taking into account muscular, articular and ligamentous components of the pelvic area. The identification of the area of altered mobility is a fundamental factor to properly organize the therapeutic work in order to improve the results. We hope that this article could represent a starting point and can be a stimulus for further manual research.

Conflicts of Interest

The authors report no conflicts of interest in this work.

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